PROCEEDINGS

OF

THE ROYAL SOCIETY.

1836. No. 25.

April 21, 1836.

RODERICK IMPEY MURCHISON, Esq., Vice-President, in the Chair.

A paper was read, entitled "Additional Observations on Voltaic Combinations." In a letter addressed to Michael Faraday, Esq., D.C.L., F.R.S. Fullerian Professor of Chemistry in the Royal Institution, &c. By J. Frederick Daniell, Esq., F.R.S., Professor of Chemistry in King's College, London.

The author has found that the constant battery, of which he described the construction in a former communication to the Royal Society, might be rendered not only perfectly steady in its action, but also very powerful; as well as extremely efficacious and convenient for all the purposes to which the common voltaic battery is usually applied. With this view he places the cells which form the battery in two parallel rows, consisting of ten cells in each row, on a long table, with their siphon-tubes arranged opposite to each other, and hanging over a small gutter, placed between the rows, in order to carry off the refuse solution when it is necessary to change the acid. Having observed that the uniformity of action may be completely maintained by the occasional addition of a small quantity of acid, he is able to dispense with the cumbrous addition of the dripping funnel; an arrangement which admits with facility of any combination of the plates which may be desired.

April 28, 1836.

DAVIES GILBERT, Esq., Vice-President, in the Chair.

Captain John James Chapman, R.A., was elected a Fellow of the Society.

On certain parts of the Theory of Railways; with an investigation of the formulæ necessary for the determination of the resistances to the motion of carriages upon them, and of the power necessary to work them. By the Rev. Dionysius Lardner, LL.D., F.R.S.

The author observes, in his prefatory remarks, that an extensive and interesting field of mathematical investigation has been recently opened in the mechanical circumstances relative to the motion of heavy bodies on railways; and having collected a body of experiments and observations sufficient to form the basis of a theory, he purposes,

in the present paper, to lay before the Society a series of mathematical formulæ, embodying the most general expressions for the phenomena of the motion of carriages on these roads.

The author begins by investigating the analytical formulæ for the traction of trains over a level line which is perfectly straight, and finds, first, the distance and time within which, with a given amount of tractive power, the requisite speed may be obtained at starting; and also the point where the tractive power must be suspended, previous to coming to rest. The excess of tractive power necessary to get up the requisite speed is shown to be equal to the saving of tractive power previous to a stoppage; and formulæ are given for the determination of the time lost under any given conditions at each stop.

The motion of trains in ascending inclined planes which are straight, is next considered; and formulæ are given combining the effects of friction and gravity, in opposition to the tractive force. The circumstances which affect every change of speed, and the excess of tractive force necessary, in such cases, to maintain the requisite speed, are determined; as well as the other circumstances already stated with respect to level planes.

The friction of trains upon descending planes is next investigated; and an important distinction is shown to exist between two classes of planes; viz., those whose acclivities are inferior to the angle of repose, and those of more steep acclivities. A remarkable relation is shown to exist between the tractive forces in ascending and descending the first class of planes. For descending planes of greater acclivity than the angle of repose, the use of breaks becomes essentially requisite. The effect of these contrivances is investigated, as well as the motion of trains on the accidental failure of breaks.

In any attempts which have been hitherto made to obtain the actual velocities acquired by trains of carriages or waggons under these circumstances, an error has been committed which invalidates the precision of the results; the carriages having been treated as sledges moving down an inclined plane. The author has here given the analytical formulæ by which the effect of the rotatory motion of the wheels may be brought into computation; this effect, depending obviously on the amount of inertia of the wheels, and on the proportion which their weight bears to the weight of the waggon.

The properties investigated in this first division of the paper, are strictly those which depend on the longitudinal section of the line, presumed to be straight in every part of its direction. There is, however, another class of important resistances which depend on the ground-plan of the road, and these the author next proceeds to determine.

The author then gives the analytical formulæ which express the resistance arising,—*first*, from the inequality of the spaces over which the wheels, fixed on the same axle, simultaneously move; *secondly*, from the effort of the flanges of the wheels to change the direction of the train; and *thirdly*, from the centrifugal force pressing the flange against the side of the rail. He also gives the formulæ necessary to determine, in each case, the actual amount of pressure produced by

a given velocity and a given load, and investigates the extent to which these resistances may be modified by laying the outer rail of the curve higher than the inner. He assigns a formula for the determination of the height which must be given to the outer rail, in order to remove as far as possible all retardation from these causes; which formula is a function of the speed of the train, the radius of the curve, and the distance between the rails.

In the latter part of the paper, the author investigates the method of estimating the actual amount of mechanical power necessary to work a railway, the longitudinal section and ground-plan of which are given. In the course of this investigation he arrives at several conclusions, which, though unexpected, are such as necessarily arise out of the mechanical conditions of the inquiry. The first of these is, that all straight inclined planes of a less acclivity than the angle of repose, may be mechanically considered equivalent to a level, provided the tractive power is one which is capable of increasing and diminishing its energy, within given limits, without loss of effect. It appears, however, that this condition does not extend to planes of greater acclivities than the angle of repose; because the excess of power required in their ascent is greater than all the power that could be saved in their descent; unless the effect of accelerated motion in giving momentum to the train could properly be taken into account. In practice, however, this acceleration cannot be permitted; and the uniformity of the motion of the trains in descending such acclivities must be preserved by the operation of the break. Such planes are therefore, in practice, always attended with a direct loss of power.

In the investigation of the formulæ expressive of the actual amount of mechanical power absorbed in passing round a curve, it is found that this amount of power is altogether independent of the radius of the curve, and depends only on the value of the angle by which the direction of the line on the ground-plan is changed. This result, which was likewise unexpected, is nevertheless a sufficiently obvious consequence of the mechanical conditions of the question. If a given change of direction in the road be made by a curve of large radius, the length of the curve will be proportionably great; and although the intensity of the resistance to the tractive power, at any point of the curve, will be small in the same proportion as the radius is great, yet the space through which that resistance acts will be great in proportion to the radius: these two effects counteract each other; and the result is, that the total absorption of power is the same. On the other hand, if the turn be made by a curve of short radius, the curve itself will be proportionately short; but the intensity of the resistance will be proportionately great. In this case, a great resistance acts through a short space, and produces an absorption of power to the same extent as before.

In conclusion, the author arrives at one general and comprehensive formula for the actual amount of mechanical power necessary to work the line in both directions; involving terms expressive, *first*, of the ordinary friction of the road; *secondly*, of the effect of inclined planes, or *gradients*, as they have been latterly called; and, *thirdly*, of the

effect of curves involving changes of direction of the road, the velocity of the transit, and the distance between the rails; but, for the reason already stated, not comprising the radii of the curves.

Although the radii of the curves do not form a constant element of the estimate of the mechanical power necessary to work the road, nevertheless they are of material consequence, as far as regards the safety of the transit. Although a short curve with a great resistance may be moved over with the same expenditure of mechanical power as a long curve with a long radius, yet, owing to the intensity of the pressure of the flange against the rail, the danger of the trains running off the road is increased: hence, although sharp curves cannot be objected to on the score of loss of power, they are yet highly objectionable on the score of danger.

In the present paper, the author has confined himself to the analytical formulæ expressing various mechanical effects of the most general kind; the coefficients and constants being expressed merely by algebraical symbols: but he states that he has made an extensive series of experiments within the last few years, and has also procured the results of experiments made by others, with a view to determine the mean values of the various constants in the formulæ investigated in this paper. He has also, with the same view, made numerous observations in the ordinary course of transit on railways; and he announces his intention of soon laying before the Society, in another paper, the details of these experiments, and the determination of the mean values of these various constants, without which the present investigation would be attended with little practical knowledge.

A paper was also read, entitled "Register of the State of the Barometer and Thermometer kept at Tunis, during the years 1829, 1830, 1831 and 1832." Presented by Sir Thomas Reade, His Majesty's Agent and Consul General at Tunis. Communicated by P. M. Roget, M.D., Sec. R.S.

The observations here registered are those of the thermometer at 9 A.M., at noon, and at 6 P.M., and the points of the wind, and height of the barometer for each day of the abovementioned years.

May 5, 1836.

FRANCIS BAILY, Esq., Vice-President and Treasurer, in the Chair.

Edward Burton, Esq., William Sands Cox, Esq., and Captain Thomas Locke Lewis, R.E., were elected Fellows of the Society.

A paper was in part read, entitled "On the Optical Phenomena of certain Crystals." By Henry Fox Talbot, Esq., F.R.S.

May 12, 1836.

The Rev. WILLIAM WHEWELL, M.A., Vice-President, in the Chair.

The reading of a paper, entitled "On the Optical Phenomena of